Magnetic Effects of Meteor Impacts

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I shall talk about a possibility which, as far as I can find out, has not been given the kind of approach that I will describe. It is known that the Earth's magnetic field changes sign in a rather random manner about once every hundred thousand years. This is a fact, and it is the only fact that I will mention. The rest is speculation.

The question is: Is there a correlation between meteor impacts on Earth and the flips of the Earth's magnetic field? If there is a correlation, it would be very interesting because it would give us an additional way to find out when meteors have hit the Earth. Some people have looked for such a correlation, but so far there is no evidence for it.

First, let us consider the Earth's magnetic field. The Earth's magnetic field is caused by a disorderly motion in the Earth's core, in the electrically conducting molten iron. According to Alfven, this motion intensifies the magnetic fields in a disorderly manner. A little order is introduced into this disorderly arrangement of magnetic fields by the Earth's rotation and the resulting Coriolis force. There are two stable arrangements of the magnetic field, one with a general lineup for the magnetic pole at the Earth's north pole and the other at the Earth's south pole.

An incoming asteroid carrying 10^{30} ergs, more or less, can have major effects. One might expect that there would be a direct effect on the currents in the Earth's core, but I don't believe this for the following reason. By the time the shock from the asteroid impact reaches the Earth's core, it is essentially sonic. And in a sonic vibration, the forward and backward motion is very similar, so whatever current changes are left behind are small and will result in no overall changes. However, in the atmosphere and outside the Earth's surface (out to a distance of two Earth radii), about one percent of the energy of the dipole field is contained, and this field can be readily altered by the incoming object.

The flips of the Earth's magnetic field have left their records in lava flows. The magnetic field has oriented magnetic dipoles in the lava while it was liquid. As the lava solidified, it preserved the record of the orientation of the magnetic field. This evidence shows that the Earth's magnetic field has changed every few hundred thousand years, and that the changes have taken a few thousand years.

There is one exception. A lava flow in Oregon shows evidence of a change that apparently occurred in a few days. Now, if the magnetic field comes from the core, it has to go through the Earth's mantle. The conductivity of the mantle results in a time delay of about ten thousand years, and nothing can change much faster. In five thousand years, yes. In a week, no!

Such a sudden change must come from an asteroid. The impact changes the magnetic field in an hour. Then, the magnetic field gets into the conducting ocean, and it gets into the top few miles of the Earth's mantle. A strongly changed field is frozen into a region of the Earth's mantle, and this can have the effect of favoring a different order in the magnetization of the Earth's core as a consequence of the impact. According to this picture, an impact need not be accompanied by a change in the magnetic field. But a change in the magnetic field will *always be introduced* by an impact. The impact will not cause the change to happen, but it will give it a chance to occur.

A very obvious question is: Will not nuclear explosions give similar effects? The answer is "No" because, given the density of the atmosphere, the effect of a nuclear explosion will be limited in volume. At a very high altitude, where the atmosphere is one-thousandth as dense as at sea level, the volume affected can be hundreds of kilometers in linear dimension or more.

How do we gather evidence for such magnetic field changes? The Air Force is looking at incoming objects that don't reach the surface. Whenever such an event occurs, there could be a mechanism to notify scientists who can look for a magnetic storm. The big objects—those that arrive once in a hundred thousand years—carry enough energy to affect the whole atmosphere, ionize much of it, move it. On the surface of the Earth, at one atmosphere, 10^3 ergs per cubic centimeter of air is a few million times as much as the magnetic energy density. And if we go up a hundred kilometers, the magnetic energy density of the air is down to one part in a million, but the magnetic field has not changed much. Now the two energy densities are comparable. As the atmosphere is moved, it will be ionized, the magnetic lines will move with the atmosphere, and there will be large regions where the magnetic energy density is multiplied severalfold.

But is this a permanent change? It is not, but a part of it is. The regions of the atmosphere where the energy density has increased will expand again. The atmosphere can expand perpendicular to the magnetic field or parallel to the magnetic field. If it moves perpendicularly, it takes the magnetic field along with it, which is apt to undo the change that has been made. But if the atmosphere expands parallel to the magnetic field, then the magnetic field will not change, and the intensification of the magnetic field will be permanent.

As the shock of the asteroid impact reaches the Earth's surface, it finds bodies that are conductors, like the ocean and the mantle. The resulting hydrodynamic changes will run their course in a few hours. The waters of the ocean will have moved quite a bit, and their motion will have occurred along whatever magnetic field exists in the ocean. In a few hours, the magnetic field will penetrate the Earth's surface to a few tens of kilometers. The penetration depth goes with the square root of the time. The resulting changes will be undone, in part, in a few hours, but some will diffuse to greater depths.

Following this line of reasoning, it may be plausible that there occur, on rare occasions for short times, violent changes followed by much slower changes. Eventually, these changes may lead to a stabilization of the Earth's magnetic fields in the opposite direction, an orientation that is as stable as the original one.

So, what are the consequences of such a happening? If the Earth's magnetic field flips between the two extremes, the magnetic field is apt to be *less* intensive for a few thousand years. This has been observed. A smaller magnetic field will allow more cosmic rays to penetrate the atmosphere. Cosmic rays can cause mutations. I do not know what percentage of mutations is caused by cosmic rays, but increasing the amount of cosmic radiation might conceivably increase the mutation rate by as much as tenfold. That is entirely unimportant. Whatever a horse would otherwise do in evolving in ten thousand years, it will now do it in a thousand years.

But there may be changes—in fact, there must be changes—that require multiple mutations. Assume that a new kind of organ will not originate if too few mutations occur. Assume that six mutations are needed to establish a new kind of an eye. A tenfold increase in the rate of single mutations will, in this case, be a millionfold increase for six mutations. Therefore, for a few thousand years, while the magnetic field is low, very extraordinary developments might go from being impossible to something that is barely possible. And if this is so, then the mass extinctions caused by asteroid impacts may be accompanied by a period of increased mutations, an increased rate that is important in the case of radical changes although unimportant in the case of gradual changes.

Audience Questions and Comments

Audience: Dr. Teller, thank you for the presentation. At the risk of never being invited back to one of these conferences, may I ask one question?

Dr. Teller: Any question—not only a question, even a statement if you wish.

Audience: I've spent my career studying the Cretaceous, and one of the curious aspects is that the middle of the Cretaceous has the longest interval, with no reversals, of the last 600 million years.

Dr. Teller: No?

Audience: A period 40 million years long and no reversals.

Dr. Teller: 40 million years—no reversals. And in the last 5 million years, I'm told there have been 23 reversals.

Audience: 40 million years and no reversals.

Dr. Teller: Do we have any evidence of asteroid strikes during this period?

Audience: Yes.

Dr. Teller: How many?

Audience: Of the strikes that are well dated, a few are certainly in this long normal period.

Audience: This is the oddest thing—no one can explain it at all why we have this one, unique, long normal period.

Dr. Teller: Well, look, the reversals *certainly* are not explained. And I think they may have more reasons than one.

Audience: Based on minor mass extinctions and the formation of new species, more often than not, stage boundaries coincide with reversals.

Dr. Teller: How long do these changes take and in how long a period do they occur?

Audience: The stages themselves are about 5 million years in length, but you find the species forming extremely rapidly, in a hundred thousand years or less.

Dr. Teller: A hit could cause a low magnetic field that could last for a few thousand years—difficult to have it last more.

Audience: But the species transitions may take longer. Once you start the ball rolling, then biology takes over and goes its own stately pace.

Audience: It's been observed in hypervelocity impact experiments that impacts do, indeed, give off magnetic pulses. I think you've identified another impact consequence—the magnetic pulse given off by the impact in the atmosphere could couple its energies into our existing flow of electrons in our society (long lines, power lines, radios, etc.). It's something that it ought to be looked at.

Audience: According to Billy Glass, who studied the problem, there are two cases in which there appears to be a very close correlation with a layer of impacts glass spherules and the reversal. One case is the last major reversal at 780,000 years ago. It's also very close to the time of emplacement of the Austro-Asian tektite shelf. And so that has been one of the reasons for suspecting there is a connection between impact and a reversal. The other case is a reversal that occurred about a million years ago. And this, too, is very close to a layer of microtektite that we know comes from a crater in Gant. The problem is that, in very careful recent studies, while the timing is close, it's not close enough. In fact, in each case, the reversal has preceded the tektite shower by a small amount.

Dr. Teller: By how much?

Audience: Well, typically by tens of centimeters of sediment, so it may be times on the order of tens or a few tens of thousands of years.

Dr. Teller: More questions?

Audience: Another point you might be interested in is that there was a well-observed magnetic pulse from a regular magnetic observatory associated with the Tunguska event.

Dr. Teller: The what?

Audience: The Tunguska fireball produced a known magnetic excursion.

Dr. Teller: *Very* good. Very good. You know, I have a proprietary interest in Tunguska. It occurred when I was half a year old.